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HIGH VOLTAGE NANOSECOND PULSE GENERATORS

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This ~~Third Interim~~ Report describes work performed during the period 1 Sep 77 to 30 Jun 78 to develop a set of high voltage nanosecond pulse generators. The objective of the development is a set of pulse generators of small volume, low weight, and high efficiency. Testing of the power supply and modulator for Task A Pulse Generator, operating either single pulse or 15 Hz at a pulsewidth of 125 ns, pulse voltage of 30kV, and pulse current of 1200 amps, has been proceeding. The power supply and modu-
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20. Abstract (continued)

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ABSTRACT

This Third Interim Report describes work performed during the period 1 Sept. 77 to 30 Jun. 78 to develop a set of high voltage nanosecond pulse generators. The objective of the development is a set of pulse generators of small volume, low weight, and high efficiency. Testing of the power supply and modulator for Task A Pulse Generator, operating either single pulse or 15Hz at a pulse width of 125ns, pulse voltage of 30kV, and pulse current of 1200 amps, has been proceeding. The power supply and modulator were integrated and operated at an intermediate level of 10kV. The modulator was tested at 30kV. Preliminary tests on an SCR-magnetic modulator for Task B Pulse Generator, providing a 5kV, 4A, 100ns pulse to the load, were conducted. In addition, a solid state pulse generator providing a 16kV, 0.5 amp, 6usec pulse to a laser load was designed, built, and tested.

I. INTRODUCTION

This report covers work done during the period 1 Sept. 1977 to 30 June 1978 on Contract DAAB07-77-C-2641 to develop a set of high voltage nanosecond pulse generators. The work is being performed by Cober Electronics in Stamford, Connecticut for the U.S. Army Electronics Command, Ft. Monmouth, New Jersey. The work is directed toward fulfilling the requirements of Technical Guidelines entitled "High Voltage Nanosecond Pulse Generators" dated 27 July 1976. Listed below are the requirements for Task A, Task B, and Task C.

Task A

a.	Output Voltage	30KV
b.	Peak Current	1200A
c.	Prr	15Hz and single pulse
d.	Pulse Width (50%)	125ns
e.	Rise Time (10% to 90%)	20ns max.
f.	Fall Time (90% to 10%)	40ns max.
g.	Pulse Energy Output	4.5 joules
h.	Pulser Efficiency	90% min. (resistive load)
i.	Life	10^6 pulses min.
j.	Weight	2.0kg max.

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k.	Volume	$360cm^3$ max.
l.	Form Factor	Cylindrical
m.	Maximum Outer Diameter	6.5cm

Task B

a.	Output Voltage	5kV
b.	Peak Current	4A
c.	Prr	10,000Hz
d.	Pulse Width (90%)	100ns
e.	Rise Time (10% to 90%)	10ns max.
f.	Fall Time (90% to 10%)	20ns max.
g.	Pulser Efficiency	90% min. (resistive load)
h.	Pulse Energy Output	0.0023 joules
i.	Life	1000 hrs. min.
j.	Weight	2.0kg
k.	Volume	$360cm^3$ max.

Task C

a.	Output Voltage	1kV
b.	Peak Current	1) 15A to charge up C_L = 30pF in 2 nsec 2) 20mA during flat top portion of pulse
c.	Prr	15,000Hz
d.	Pulse Width (50%)	20ns
e.	Rise Time (10% to 90%)	2ns max.
f.	Fall Time (90% to 10%)	4ns max.
g.	Pulser Efficiency	90% min.

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h.	Life	1000 hrs. min.
i.	Weight	2.0kg max.
j.	Volume	$360 cm^3$ max.

II. TASK A

Presented in Figure 1 and Figure 2 are schematic diagrams for the power supply and modulator for the Task A pulse generator. The 30kV, 1200A, 125ns pulse is formed by discharging a Blumlein circuit with a triggered spark gap. A ringing-choke dc-to-dc converter charges the Blumlein circuit capacitors to 30kV by transforming the 28 volt input.

In the present design, the 30kV output is formed by connecting the three secondary windings of power supply transformer T_1 in series. Each secondary consists of 2500 turns of wire wound over a separate molypermalloy toroid core. The secondary start and secondary finish are terminated in corona rings separated by 0.5 inch. Each core has an outer diameter of 1.33 inches, an inner diameter of 0.76 inches, and a height of 0.46 inches. Adjacent cores are separated by 0.5 inch. The primary winding passes through the center window of all three cores and is insulated to withstand the 30KV potential difference between primary and secondary. The drive winding of transformer T_1 passes through the center of all three cores and over the primary winding. It is insulated for 15kV. Figure 3 shows a photograph of the transformer configuration utilizing two cores with the secondary windings in series.

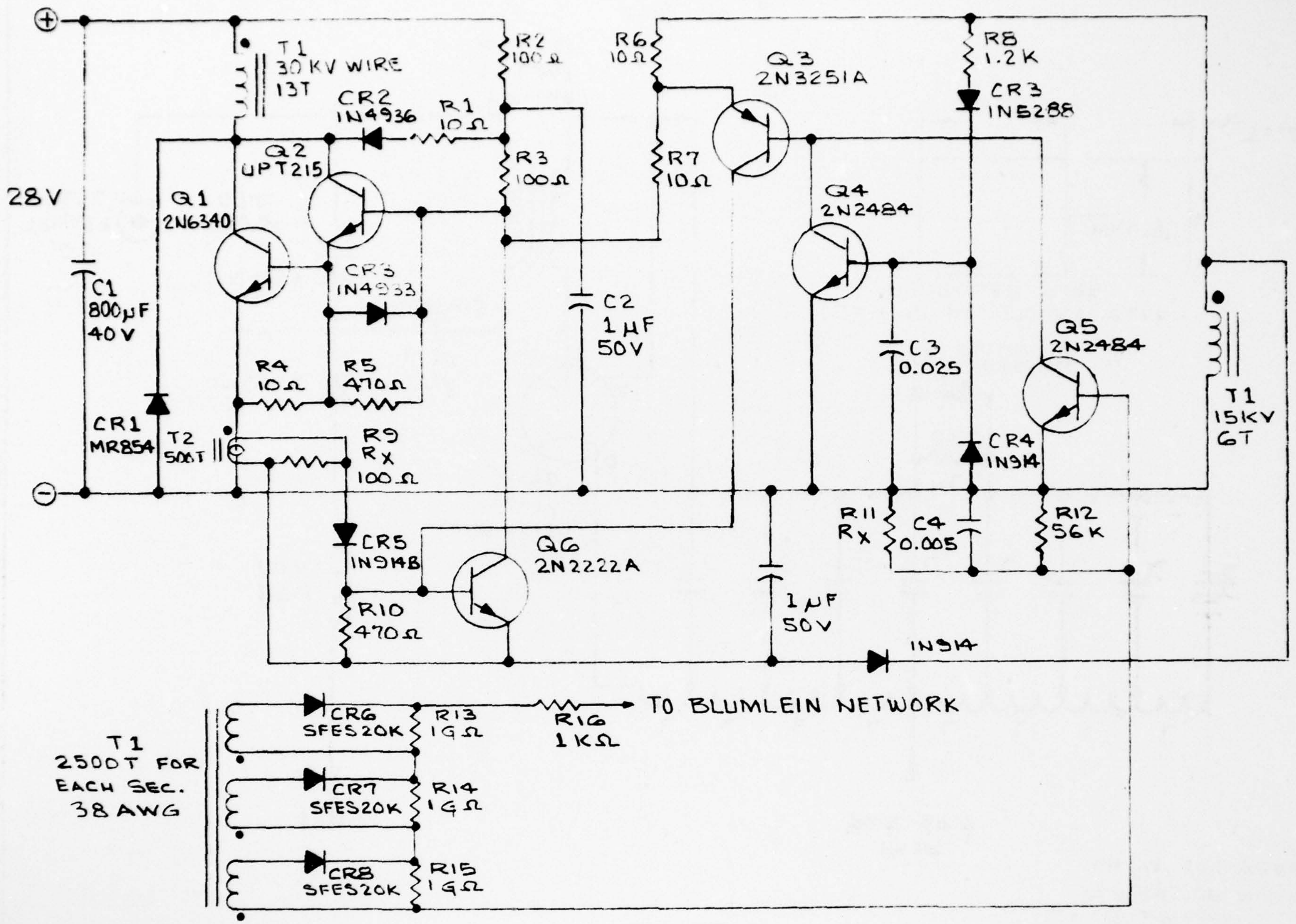

FIGURE 1
TASK A POWER SUPPLY

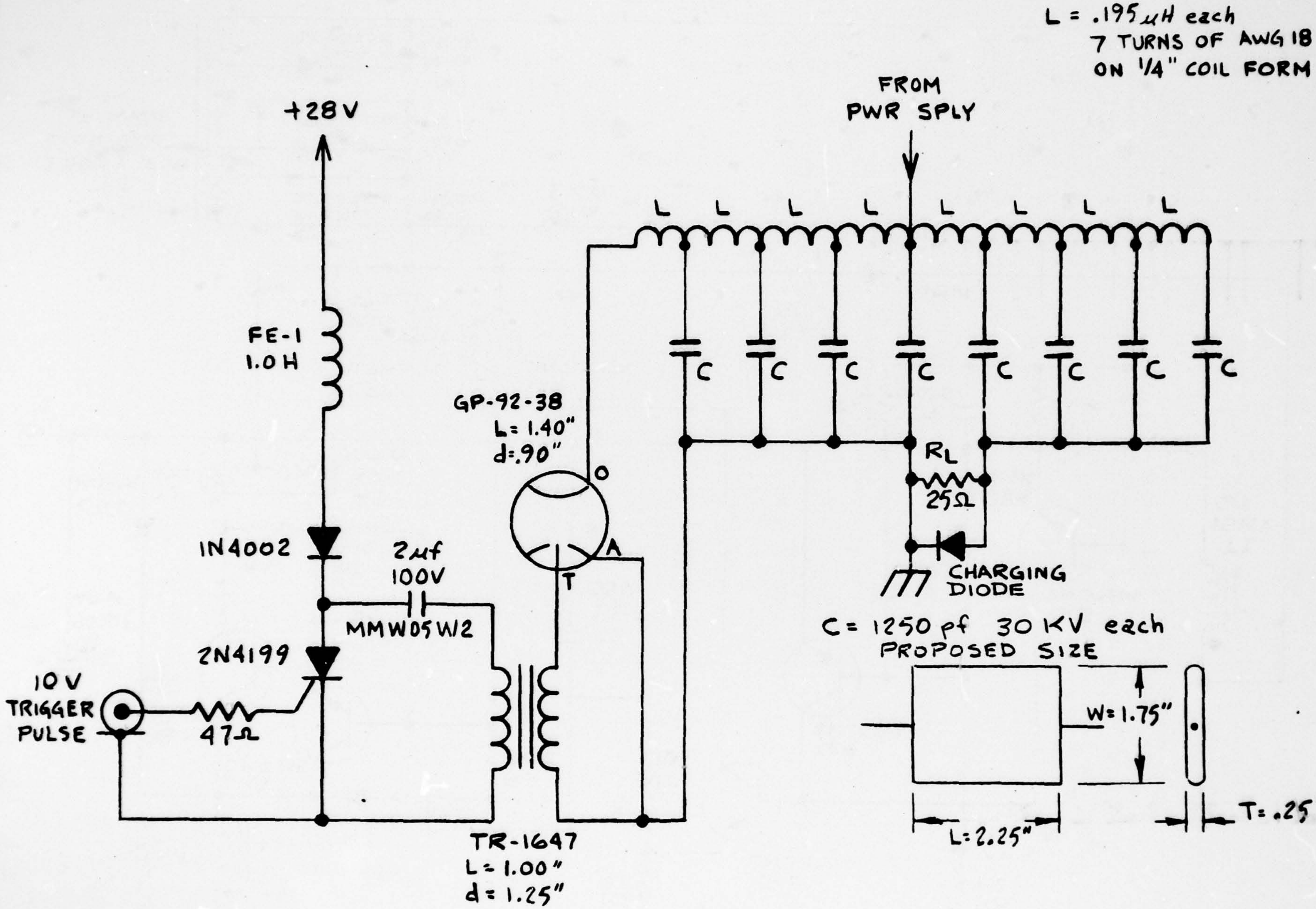

FIGURE 2
TASK A MODULATOR

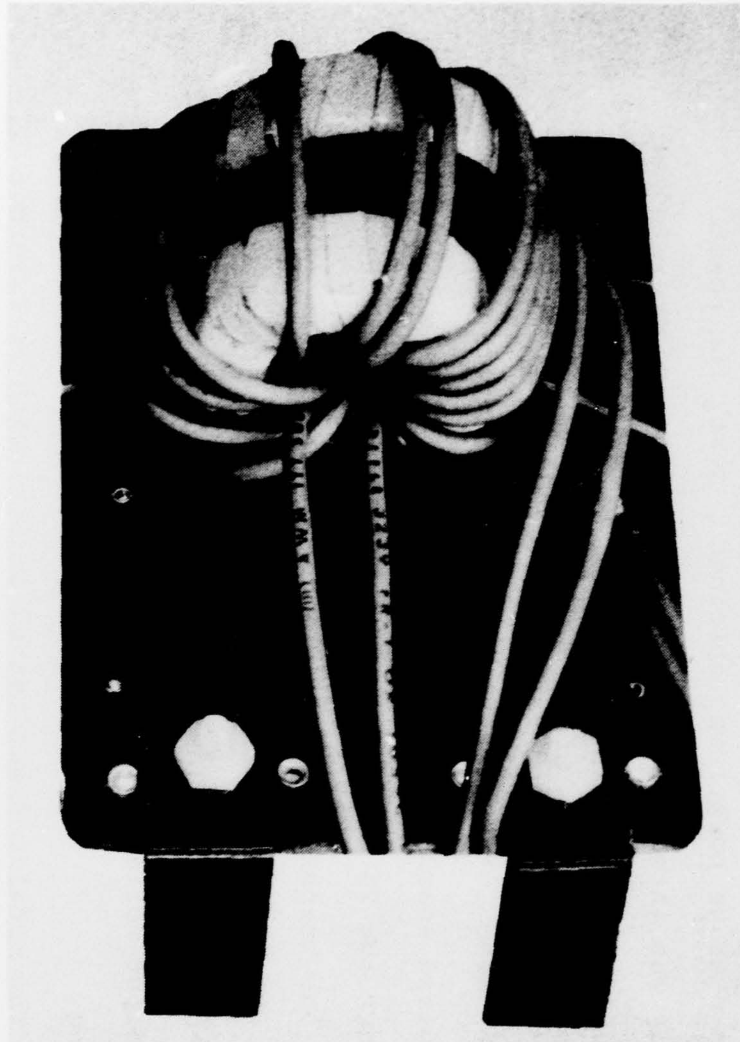

FIGURE 3
TASK A HV TRANSFORMER

Testing on the Task A Pulse Generator was begun by modifying the power supply for 10kV operation. The primary and control windings were wound on one of the three toroids to be used in the 30kV design. The power supply was operated into a 1 megohm resistive load. With an input voltage of 10 volts, an output voltage of 5kV (25 watts average power) was obtained. Next, the power supply was integrated with the modulator and operated at a pulse repetition rate of 15Hz. The Blumlein circuit capacitors were charged to a peak voltage of 10kV during the 67 msec interpulse period. Upon triggering the triggered spark gap, a pulse current of 400A was measured through the 25 ohm load at the output of the modulator.

The transformer configuration utilizing two cores with the secondary windings in series was operated into a 2 megohm resistive load. With an input voltage of 24 volts, an output voltage of 10kV (50 watts average power) was obtained.

The modulator was tested at 30kV with an external supply. A pulse current of 1200 amps at a pulse width of 140ns and pulse repetition rate of 15Hz was measured through the 25 ohm load. The pulse rise and fall time were approximately 40ns. Figure 4 shows a photograph of the modulator breadboard.

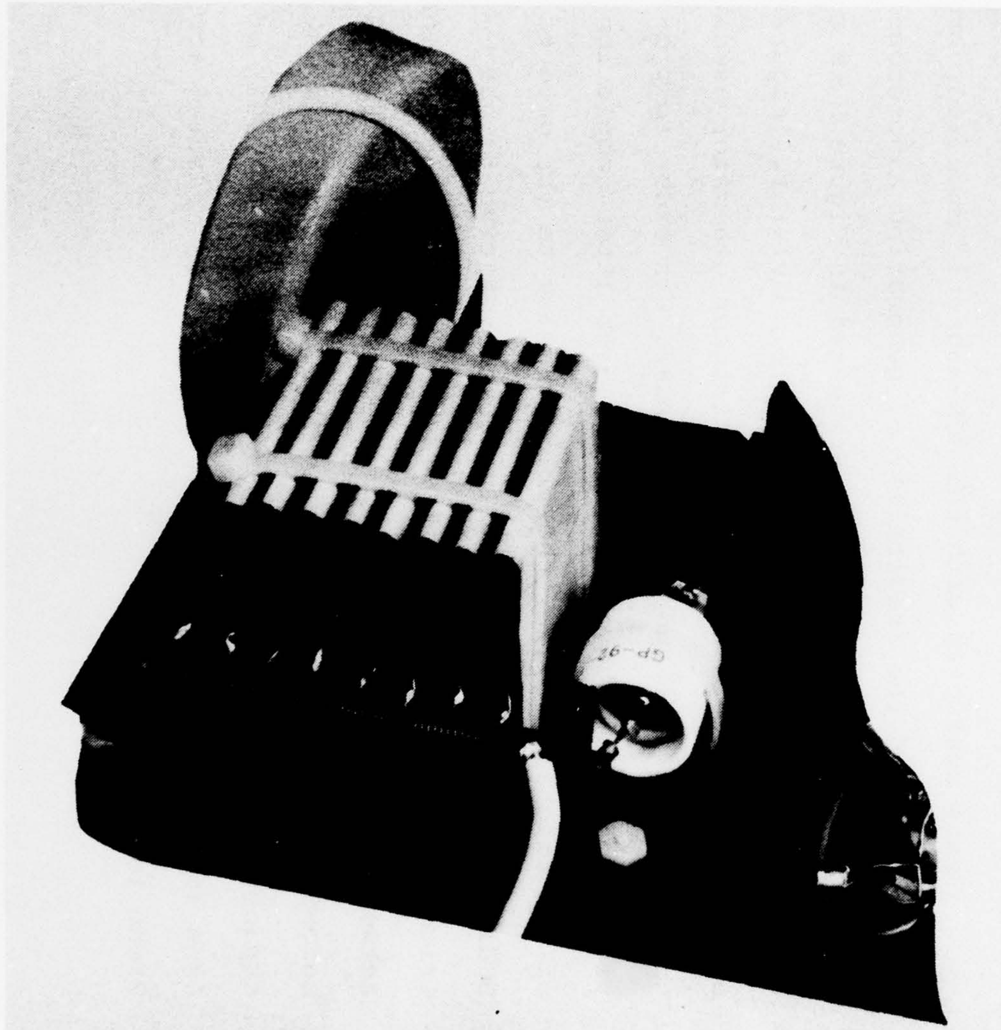

FIGURE 4
TASK A MODULATOR

III. TASK B

Tests conducted with the SCR-magnetic modulator breadboard confirmed the feasibility of generating nanosecond pulses with a 28 volt input. Presented in Figure 5 is a schematic diagram of the SCR-magnetic modulator. Figure 6 shows a schematic diagram of the trigger generator used to gate charging SCR1 and discharge SCR2. In order to provide time for discharge SCR2 to recover after completion of the discharge cycle, the trigger pulse to the gate of SCR1 was delayed approximately 20usec relative to the trigger pulse to the gate of SCR2. With a single section network consisting of the saturated inductance of the secondary winding of saturating transformer T_1 and a 250 pF capacitor, a 4kV pulse having a pulse width (90%/50%) of 40ns at a pulse repetition rate of 5KHz was measured across a 2Kohm load.

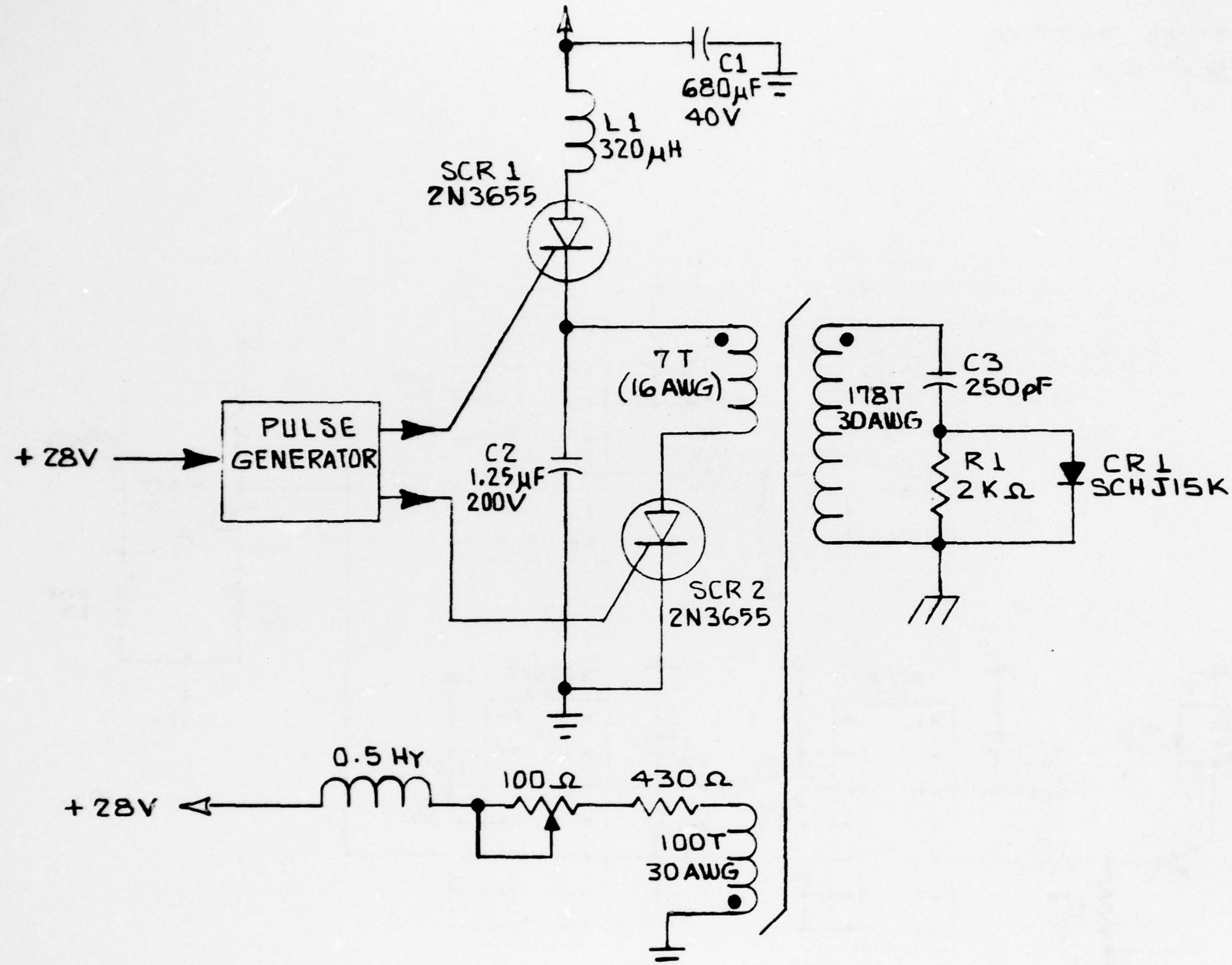

FIGURE 5
TASK B MODULATOR

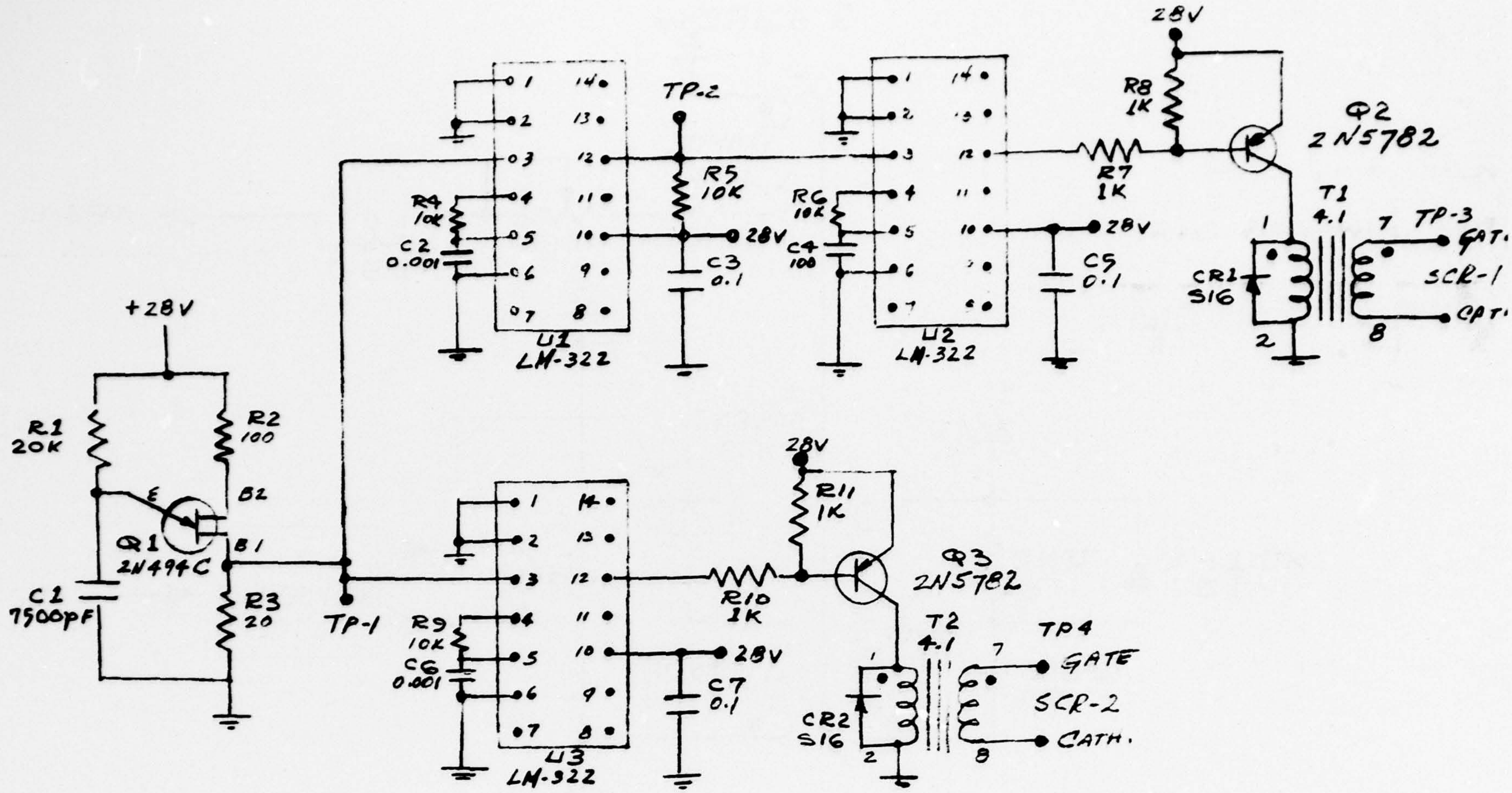

FIGURE 6
TRIGGER GENERATOR FOR
MAGNETIC MODULATOR

IV. 16KV PULSE GENERATOR

As part of the Task B effort, a higher voltage, lower current exploratory version of the original Task B pulser was investigated. The solid-state pulse generator to trigger the laser tube was designed, built, and tested. Operating from a 115VAC input, the output was a 16kV, 6usec pulse capable of driving a 0.5 amp load. Figure 7 shows a schematic diagram of the pulser generator.

The 115 volt line is rectified and doubled by a full wave doubler circuit. The rectified voltage, approximately 300 volts, is applied to the primary of a step-up pulse transformer by six Darlington transistors connected in parallel. To speed up the turn off process, external anti-saturation diodes are used at the bases.

Control circuit power is derived from one 9 volt and two 1.5 volt batteries. The batteries are adequate for the designed life of the pulser and eliminate the need of a separate transformer to provide the two voltages. The 9 volt alkaline battery is rated at 100mA for 1 hour. The 1.5 volt carbon-zinc batteries are rated at 100mA for 8 hours. To conserve power and to prevent damage to the Darlington transistors, the battery switch must be turned on shortly prior to the application of 115VAC input power and turned off only after removal of 115VAC input.

TTL crystal oscillator U1 generates a 10KHz clock

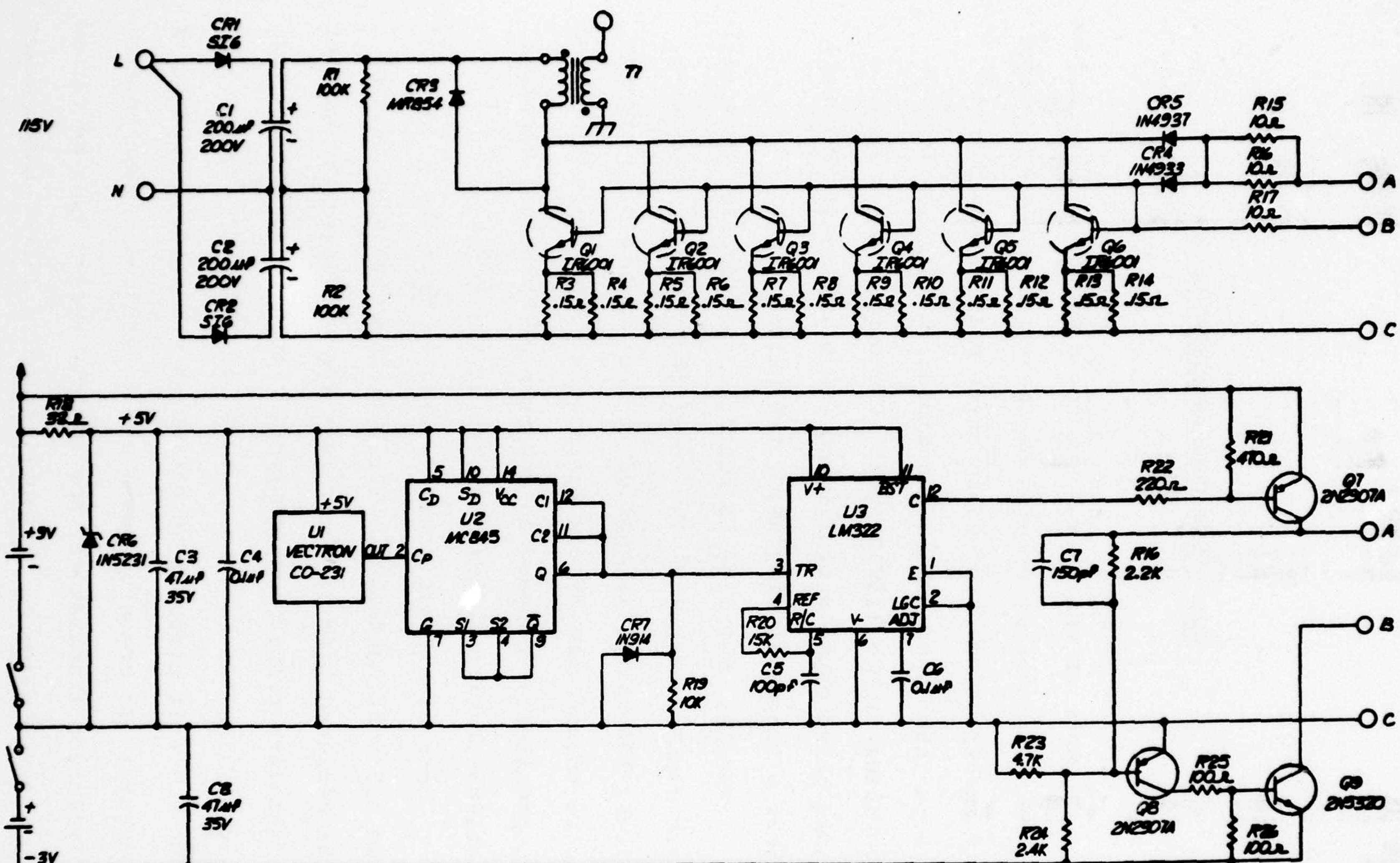

FIGURE 7
16 KV PULSE GENERATOR

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pulse. Flip-flop U2 determines the output repetition rate of 5KHz by dividing the 10KHz clock pulse by two. Timer U3 generates an approximately 2 usec wide pulse at the 5KHz repetition frequency. Transistor Q7 provides base drive to turn the Darlington transistors on. Transistor Q9 provides negative drive to enhance turn off.

V. CONCLUSIONS

Based on breadboard tests of the Task A Pulse Generator at an intermediate level of 10kV, a practical approach has evolved to generate high voltage, high current nanosecond pulses from a 28 volt input. At the 10kV level, a pulse current of 400A was measured through the 25 ohm load. Breadboard tests on the modulator at 30kV, when operated with a laboratory high voltage power supply, resulted in a pulse current of 1200A at a pulse width of 140ns. The pulse rise and fall time were approximately 40ns.

Breadboard tests on the SCR-magnetic modulator for the Task B Pulse Generator resulted in a 4kV, 40ns pulse into a 2Kohm load with a 28 volt input.

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